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Editorial

Letter from the Editors

The *Journal of Safety Research* is pleased to publish in this special issue the proceedings of several papers presented at the 4th International Conference on Road Safety and Simulation convened at Roma Tre University in Rome, Italy, October 2013. This conference serves as an interdisciplinary forum for the exchange of ideas, methodologies, research, and applications aimed at improving road safety globally.

Conference proceedings provide the opportunity for research in its formative stages to be shared, allowing our readers to gain early insights in the type of work currently being conducted and for the researchers to receive valuable feedback to help inform ongoing activities. This conference in particular offers an array of research topics not often covered by this journal from researchers practicing in over 11 countries. As is common with publishing conference proceedings, the papers published in this issue did not go through the normal *JSR* review process. Each paper included in this issue did meet the Road Safety and Simulation conference review requirements. They reflect varying degrees of scientific rigor, methodological design, and groundbreaking application.

The proceedings published in this special issue of *JSR* draw from the following road safety research sectors represented at the conference: driving simulation, crash causality, naturalistic driving, and new research methods.

It is our hope that the publication of these important proceedings will stimulate vigorous dialogue, rigorous research, and continuing innovative initiatives and applications, leading, ultimately, to fewer traffic fatalities, injuries, and crashes.

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Relationships between frequency of driving under the influence of cannabis, self-reported reckless driving and risk-taking behavior observed in a driving simulator

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ABSTRACT

Introduction: The role of cannabis consumption in traffic crashes is unclear and the causal link between cannabis and collisions is still to be demonstrated. While cannabis use is very likely to impair driving ability, there is as yet no overwhelming evidence that cannabis use in isolation contributes more to collisions than other characteristics inherent to cannabis users. As noted in a growing body of literature, individuals driving under the influence of cannabis (DUIC) seem to exhibit a general reckless driving style putting them at higher risk to be involved in traffic crashes. *Method:* This study aims at investigating the relationship between self-reported DUIC and reckless driving by means of self-reported measures and direct observations made in a driving simulator. Participants (n = 72) were required to be between 18 and 25 years of age, to hold a valid driver's license, and to drive at least twice a week. They completed standard driving simulation tasks recreating everyday on-road trivial conditions. *Results:* Results show that people admitting that they commit more real-life dangerous driving behaviors reached higher maximum speed and demonstrated more reckless driving behaviors on the driving simulation tasks. Self-reported DUIC is associated with a risky driving style including a broad range of reckless on-road behaviors and support the problem driving behavior theory. Moreover, beyond confounding factors, both self-report DUIC and observed dangerous behaviors are associated with real-life traffic violations. *Practical applications:* Since DUIC appears to be related to an overall reckless style of driving, it is proposed that public safety policies should be more holistic, simultaneously targeting multiple on-road dangerous behaviors for intervention.

1. Introduction

Over a span of 20 years, rates of cannabis use have actually doubled in the very countries in which driving under the influence of alcohol (DUIA) and other risky driving behaviors have been reduced. Despite being regulated in many jurisdictions, cannabis is the most frequently consumed illegal drug worldwide, and its use appears to be an increasingly common phenomenon (Johnson, Kelley-Baker, Voas, & Lacey, 2012; Thompson, 2012; World Drug Report, 2011; Young, 2011). Results from the 2009 Canadian Alcohol and Drug Use Survey have indicated that 11.4% of Canadians overall and 33% of those aged 15–24 years used cannabis at least once in the previous year (Young, 2011). In fact, adolescents and young adults are, as a general rule, the most frequent users of cannabis. Extrapolating from surveys, more than 70% of individuals between 18 and 25 years of age have consumed cannabis at least once in their lives, while up to 30% of these same individuals will have used cannabis within the 12 previous months. At the same time, cannabis is only second to alcohol among psychoactive substances found in the bodily fluids of drivers involved in collisions (Beasley, Beirness, & Porath-Waller, 2011). Further deconstruction of these figures reveals that cannabinoids can be detected in the bodily fluids of 1.4% to 27.5% of all drivers killed in driving accidents and in 5% to 15.7% of all drivers who have been injured in crashes (Beirness & Porath-Waller, 2009). Studies of American, European, and Australian drivers have yielded comparable figures (Drummer et al., 2004; Laumon, Gadegbeku, Martin, & Biecheler, 2005; Lenné et al., 2010). Converging with these histological findings are self-reported rises in driving after using cannabis. Although the total number of drivers who engage in DUIC is relatively low, DUIC is disproportionately prevalent among young drivers. Nearly a quarter (23%) of drivers between 18 and 19 years of age report having DUIC in the 12 months preceding their participation in surveys (Walsh & Mann, 1999). Even more striking is the finding of DUIC occurring among high school students (Asbridge, Poulin, & Donato, 2005). In fact, DUIC occurs more frequently than DUIA; Beirness and Porath-Waller (2009) found that 19.7% of their respondents, nearly all of whom were male teenagers,

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reported using cannabis immediately prior to driving in the preceding year.

As noted in an up to date meta-analysis (Asbridge, Hayden, & Cartwright, 2012), a lack of consensus exists on whether the risk of motor vehicle collisions is elevated or lowered when drivers have recently consumed cannabis. Much of the early research assessing the effects of cannabis (marijuana) on driving performance was done in experimental settings in measuring basic cognition and psychomotor functions. The results of these studies are generally consistent: at increased doses, cannabis impairs a variety of skills involved in the driving task. Delta9 tetrahydrocannabinol (THC), the active metabolite of cannabis, induces dose-related decrements in short-term memory, divided attention and vigilance, reaction time, tracking, and coordination (Kurtzthaler et al., 1999; Moskowitz, 1985). As noted by Lenné et al. (2010) and by Richer and Bergeron (2009), more ecologically valid research using driving simulators, in closed and open driving circuits, indicated that moderate and high concentrations of THC also decrease the ability to maintain stable driving as measured by increases in speed and lateral position variability and by headway variability.

Studies looking at the risk of collision associated with DUIC have yielded contradictory results. Some studies have found an increase (Drummer et al., 2004; Laumon et al., 2005); others have found that cannabis use does not appear to be associated with an increase in collision risk (Bates & Blakely, 1999; Smiley, 1999). A population survey of a representative sample of adult drivers (Mann et al., 2007) revealed that the odds of reporting collision involvement were significantly higher among cannabis users and among those who reported driving after cannabis use. More recently, a systematic review of observational studies and meta-analysis of studies examining acute cannabis consumption and motor vehicle collisions (Asbridge et al., 2012) found a near doubling of risk of a driver being involve in a collision resulting in serious injury or death; the influence of cannabis use of minor collisions remains unclear.

A further point to consider is that, while cannabis use is very likely to impair driving ability, there is as yet no overwhelming evidence that cannabis use in isolation contributes more to motor collisions than other characteristics inherent to cannabis users. As noted in a growing body of literature, individuals driving under the influence of cannabis seem to exhibit a general reckless driving style, putting them at higher risk to be involved in traffic crashes (Bédard, Dubois, & Weaver, 2007; Fergusson, Horwood, & Boden, 2008; Kilmer, Hunt, Lee, & Neighbors, 2007; Lopez-Quintero & Neumark, 2010). In a recent study, Richer and Bergeron (2009) compared DUIC drivers and non-DUIC drivers with respect to self-reported dangerous driving habits, behaviors observed in a driving simulator, psychological predictors and crash involvement. Results indicated that sensation seeking and impulsivity are independent psychological predictors of DUIC and suggest that DUIC is associated with self-reported and observed risky driving. This study confirms that self-reported cannabis use is associated with a risky driving style (Fergusson et al., 2008), including a broad range of dangerous on-road behaviors, and supports the problem driving behavior theory (Jessor, Donovan, & Costa, 1991; Jonah, 1990). It seems important to control for dangerous driving habits when assessing the association between DUIC and collision involvement. A general dangerous driving style could contribute to an over-estimation of DUIC-related collisions among DUIC drivers.

1.1. Objectives

This study aims at investigating the relationship between reckless driving and frequency of DUIC among young cannabis users, by means of self-reported measures and direct observations made in a driving simulator. A second objective was to verify the relative contribution of sensation seeking, impulsivity, age, and driving exposure in the prediction of DUIC. Finally, DUIC was further associated with the probability of being involved in a collision or a traffic violation while controlling for potential confounding variables (i.e., age, driving exposure, dangerous driving, and DUIA).

2. Method

In total, 72 adult males took part in the present study. Only cannabis users were recruited in order to assess the importance of the frequency of DUIC among young cannabis users, rather than the differences between users and non-users of any age, as did previous studies (Freeman, Scott-Parker, Wong, & Haworth, 2012; Lenné et al., 2010; Richer & Bergeron, 2009; Smiley, 1999; Terry & Wright, 2005). Moreover, only men were recruited as participants since empirical data exist that clearly show them to engage in more reckless driving and/or DUIC than women (Beirness & Beasley, 2009; Blows et al., 2005). Inclusion criteria were as follows: participants were required to be between 18 and 25 years of age, to hold a valid driver's license, and to drive at least twice a week. These prerequisites were necessary to ensure an adequate degree of homogeneity of knowledge of the Highway Safety Code as well as a minimum level of driving exposure among participants. An initial pool of potential participants who fulfilled these criteria was recruited via advertisements posted on the internet and on college and university message boards. Respondents to these advertisements were then subjected to a confidential telephone interview to further identify those who had engaged in “cannabis use”, defined as having consumed cannabis at least once in the 12 immediately preceding months. The first 72 young drivers identified through the telephone interview as cannabis users who have agreed to come to the lab and completed all questionnaires and simulation tasks were then entered in the present study.

Information on pertinent individual characteristics was collected via self-report. As a group, participants had a mean age of 21.94 years (SD = 1.78) and had used their vehicle an average of 4.61 days per week (SD = 1.97) during the past year. In terms of driving exposure, 15.3% of the present participants drove less than 5,000 km/year, 29.2% drove between 5,000 and 10,000 km/year, 23.6% drove between 10,000 and 20,000 km/year, and 29.2% drove between 20,000 and 40,000 km/year. Two participants reported driving more than 40,000 km/year.

2.1. Equipment

Participants completed several driving simulation tasks in a fixed-based driving simulator specially designed for research on road safety (Baumberger, Bergeron, Fluckiger, Paquette, & Delorme, 2006; Richer & Bergeron, 2009). The simulator consists of a Honda Civic (with only its engine removed) installed in the center of a room. The Civic is facing a (3 m by 2.45 m) curved screen. A ceiling-mounted projector is used to display an interactive virtual driving environment on the screen, viewed in first-person perspective by a participant sitting in the driver's seat. Surrounding scenery consists of grass, bushes, tress, and houses. All controls (i.e., steering wheel and gas and brake pedals) and indicators (e.g., speed) are superficially operational and interactive. The simulator is also equipped with a vibration device and sound system that reproduce vibratory motions and driving sounds one would encounter during a real driving experience. Effectively, all aspects of the simulator are designed to enhance the verisimilitude of participants' virtual driving experience in the study.

2.2. Questionnaires

The amount of cannabis consumption among participants was categorized as a function of frequency of cannabis use over the 12 months prior to participation. Frequency was determined via answers that participants gave in response to the following question: “How often do you consume cannabis?” Possible responses were restricted to the following choices: never, less than once per month, one to two times per month, weekly, two to three times a week, four to six times a week, and daily. Similarly, DUIC was categorized as a function of the relative frequency of driving in the hour following cannabis smoking in the 12 month

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period directly preceding the current study. The one-hour time frame following cannabis consumption was chosen because studies demonstrated that the cannabis intoxication is higher for this period (Berghaus, Scheer, & Schmist, 1995). Answers were given on a five-point Likert scale ranging from 1 "never" to 5 "always."

The French version of the *Dula Dangerous Driving Index* (DDDI) (Dula & Ballard, 2003; Willemsen, Dula, Declercq, & Verhaeghe, 2008) was employed to discern the presence of dangerous driving habits among the participants. The DDDI consists of 28 items that, taken together, provide a measure of the frequency with which individuals exhibit one of the following three types of dangerous driving behavior: Aggressive driving, risky driving, and negative cognitive/emotional driving. Responses to items are scaled by way of a five-point Likert scale ranging from 1 "never" to 5 "always." Participants are attributed a total "dangerous driving" score, as well as specific scores for each of the above-mentioned three types of dangerous driving. Developed by Richer and Bergeron (2012), the French version of the scale was found to have good internal consistency for each of the three constructs and for the total score: aggressive driving ($\alpha = 0.74$), negative emotional driving ($\alpha = 0.80$), risky driving ($\alpha = 0.76$), and dangerous driving total score ($\alpha = 0.88$).

Self-reported numbers of traffic violations and road crashes involving at least material damage occurring in the three preceding years were also noted. This time span was chosen in order to limit memory bias and to ensure enough variance since accidents and traffic tickets constitute rare events (Elander, West, & French, 1993).

Sensation seeking was assessed with the French version of the *Sensation Seeking Scale Form V* (SSS-V) (Carton, Lacour, Jouvent, & Widlocher, 1990; Richer & Bergeron, 2012; Zuckerman, 1994). This self-report scale is composed of 40 items. Each item has two possible forced-choice answers; scores from four subscales contribute to an overall sensation seeking score. These subscales evaluate the following: boredom susceptibility, disinhibition, thrill and adventure seeking, and experience seeking. For the purpose of the study, only the overall score was used. The total scale presented an excellent internal consistency ($\alpha = 0.83$).

To evaluate the impulsivity of each participant, the French version of the Barratt Impulsiveness Scale, Version 10 (BIS-10) was administered to all subjects (Bayle et al., 2000; Patton, Stanford, & Barratt, 1995). This questionnaire is composed of 34 questions to which respondents furnish answers on a four-point Likert scale ("1" denotes "never/rarely" and "4" denotes "nearly always/always"). On this questionnaire, scores of "4" denote the most impulsive response to a given item. Overall, achieving higher scores on this scale denotes higher levels of impulsivity. The scale was found to have good internal consistency ($\alpha = 0.78$).

2.3. Procedure

Each participant was given both a brief description of the study as well as assurances that the confidentiality of all information and observations gathered would be maintained. Informed consent was obtained from each participant before he began any task. Each participant was then administered un-timed self-report questionnaires to complete. Following completion of the questionnaires, participants were further required to perform a driving task in the driving simulator.

The driving task consisted of two phases. First, participants were asked to perform a virtual drive for about 15 min to become familiarized with the handling of controls in the simulator as well as the interactive environment. In this virtual drive, participants encountered intersections, road signs, and markings. No specific responses were requested of them during the trial run. In addition to familiarization, the goal of administering the practice phase was to (gradually) elicit the natural driving behaviors and habits of the participants (Reimer, D'Ambrosio, Coughlin, Kafrissen, & Biederman, 2006). The second phase consisted of the experimental condition proper. In this condition, participants were required to complete a virtual drive in the same environment to which they were exposed during the practice phase. However, time pressure was added. More specifically, participants were required to reach a particular destination in the virtual environment within a set time interval, all the while avoiding collisions. This driving goal was selected because it represented a common driving task in real life that often increases risk-taking behavior among drivers; in effect, increasing time pressure is associated with increasingly reckless driving (De Pelsmacker & Janssens, 2007). Prior to beginning the experimental task, experimenters explicitly stated the following to all participants: "You will have enough time to arrive punctually from Point A to Point B by driving at a normal pace (i.e., driving in such a way so as to respect the rules of the Highway Code)." Once all tasks were completed, participants were debriefed and given $30 as compensation.

3. Results

All study participants had a valid driving license and were self-admitted cannabis users. With respect to DUIC (i.e., engaging in driving within one hour of consuming cannabis), 48.6% of participants admitted to have always or often done so, 38.8% reported to have sometimes or rarely driven under the influence of cannabis, whereas 12.5% of them claimed to have never driven immediately after consuming cannabis. Inter-correlations between self-reported variables are presented in Table 1. The frequency of cannabis consumption was found to be significantly correlated with DUIC ($r(72) = 0.78$; $p < 0.01$), with sensation seeking ($r(72) = 0.35$; $p < 0.01$), and with risky driving ($r(72) = 0.31$; $p < 0.01$). DUIC was positively and significantly correlated to risky driving ($r(72) = 0.44$; $p < 0.01$) and to sensation seeking ($r(72) = 0.41$; $p < 0.01$). Finally, risky driving was also correlated with DUIA ($r(72) = 0.32$; $p < 0.01$) and impulsivity ($r(72) = 0.25$; $p < 0.05$), and impulsivity was related to sensation seeking ($r(72) = 0.29$; $p < 0.05$).

In order to distinguish specific predictors and their relative contribution to self-report DUIC, a hierarchical linear regression analysis using the "enter" method was performed (see Table 2). Age and driving exposure were entered on Step 1. Thereafter, psychological predictors, sensation seeking and impulsivity were included in the model followed by the interaction term between the two variables. The purpose of this analysis was to verify whether individuals scoring high in sensation seeking and impulsivity might drive more often under the influence of cannabis compared to individuals scoring high on only one of the personality traits. The final model was statistically significant ($F(5, 66) = 7.82$, $p < 0.01$) and contributed greatly to the total variance ($\Delta R^2 = 0.29$; $p < 0.01$). The interaction effect between sensation seeking and impulsivity was not significant. Sensation seeking appeared to be an important predictor of DUIC ($\beta = 0.48$; $p < .01$).

The next step involved is to determine the relationships between DUIC, the measure of self-reported risky driving, and more objective measures observed in the driving simulator, namely the maximum speed during simulation tasks and an aggregate score of risky behaviors.

Table 1
Inter-correlations among self-reported variables (n = 72).

Variables	1	2	3	4	5	6	7	8
1) Age	–							
2) Driving exposure	0.31**	–						
3) Cannabis use	0.19	0.04	–					
4) DUIC	0.03	0.13	0.78**	–				
5) DUIA	0.04	0.03	0.10	0.21	–			
6) Sensation seeking	−0.04	−0.14	0.35**	0.41**	0.09	–		
7) Impulsivity	0.02	−0.18	0.19	0.07	−0.06	0.29*	–	
8) Risky driving (DDDI)	0.10	0.20	0.31**	0.44**	0.32**	0.25*	0.09	–

* $p < 0.05$.
** $p < 0.01$.

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Table 2
Predictors of driving under the influence of cannabis ($n = 72$).

	Variables	*B*	*SE*	*β*	*t*	R^2	*c*
Step 1	Age	−0.01	0.01	−0.05	−0.49	0.02	
	Driving exposure	−0.05	0.08	0.06	−0.46		
Step 2	Impulsivity	0.04	0.02	0.21	1.26		
	Sensation seeking	0.09	0.04	0.48	4.46**	0.37	0.29**
Step 3	Interaction impulsivity × sensation seeking	0.01	0.01	0.10	1.03	0.21	0.02

* $p < 0.05$.
** $p < 0.01$.

In order to compute the latter variable, a factorial analysis in principal component was performed on three types of behaviors: tailgating, dangerous overtaking, and omitting a stop. A single factor (Eigenvalue = 1.79) could be extracted, which explained 64.1% of total variance. The construct validity of behavioral measures was tested by correlating maximum speed and the aggregate score with self-reported measures of dangerous driving. Correlations, presented in Table 3, show an association between maximum speed and self-report risky driving ($r(72) = 0.56$; $p < 0.01$). The aggregate score of observed dangerous driving was significantly correlated with self-report risky driving ($r(72) = 0.26$; $p < 0.05$). These results suggest that people admitting that they commit more real-life dangerous driving behaviors reached higher maximum speed and demonstrated more reckless driving behaviors on the driving simulation tasks.

The frequency of cannabis use ($r(72) = 0.28$; $p < 0.05$) and frequency of DUIC ($r(72) = 0.34$; $p < 0.05$) were related to maximum speed. These findings corroborate the associations between DUIC and self-reported risky driving. Sensation seeking was also related to maximum speed ($r(72) = 0.32$, $p < 0.05$). The low number of behaviors observed might have induced a lack of variance affecting analyses, which may explain why the strength of correlations between self-reports and observed behaviors is consistently higher for maximum speed than for the aggregated score of reckless behaviors.

Finally, analyses were conducted to assess the association between self-reported DUIC and the drivers' record in real world driving. In total, 38.9% of the sample (n = 28) reported one or more road crashes involving at least material damage in the past three years, and 55.6% (n = 40) reported one or more traffic tickets during the same period. These variables were dichotomized (0 = absence; 1 = presence) to account for their skewed distribution. In either case, a logistic regression was conducted in order to verify the relative risk of collisions or traffic tickets for DUIC while adjusting for confounding effects of age, driving exposure, risky driving, and DUIA. As regards involvement in accidents, although the number of events seems to increase with self-reported risk-taking behavior, and also with DUIA and DUIC, the model is not statistically significant. DUIC cannot be associated with the probability of being involved in a crash. With respect to the prediction of involvement in traffic violations, however, the model is statistically significant ($\chi^2(5) = 12.27$; $p < 0.01$) but presented a modest adjustment (R^2 Nagelkerke = 0.17). Results show that age, driving exposure, and risky driving are each positively and significantly associated with the outcome variable. DUIC is also significantly associated with an increased risk of violations (olds ratio = 1.77; $p < 0.05$). So, after controlling for confounding factors, DUIC may constitute a risk factor for traffic violations involvement.

Table 3
Two-tailed Pearson product–moment correlations (n = 72).

Self-report variables	Observed behaviors on simulation tasks	
	Maximum speed	Aggregate score
Frequency of cannabis use	0.28*	0.08
Frequency of DUIC	0.34*	0.19
Frequency of DUIA	0.12	0.11
Self-report risky driving (DDDI)	0.56**	0.26*
Sensation seeking (SSS-V)	0.32*	0.06
Impulsivity (BIS-10)	0.14	0.08

* $p < 0.05$.
** $p < 0.01$.

4. Discussion

The primary goal of this study was to investigate the relationship between self-reported DUIC and reckless driving by means of self-reported measures and direct observations made in a driving simulator. Results show that DUIC is related to self-reported risky driving measured by the DDDI. The association of frequency of DUIC with speeding observed in the driving simulator and with an aggregate score of observed risky behaviors (tailgating, dangerous overtaking, and omitting a stop) corroborates findings based on self-reports. These results are consistent with findings reported by prior studies (Bédard et al., 2007; Downey et al., 2013; Fergusson et al., 2008). However, the correlation between DUIC and self-reported risky driving is higher than the direct observation of risky driving on simulation tasks. This finding may be caused by shared method error between self-reported measures. It is also possible that risky driving may be more accurately assessed by the DDDI with the inclusion of multiple manifestations of on-road risk-taking in comparison of the more restricted behaviors that can be measured in simulation tasks (Richer & Bergeron, 2009). Taken together, these results indicate that self-reported DUIC is associated with a risky driving style including a broad range of reckless on-road behaviors and support the problem driving behavior theory (Fergusson et al., 2008; Jessor et al., 1991; Jonah, 1990).

The second objective of the present study was to verify the relative contribution of sensation seeking, impulsivity, age and driving exposure in the prediction of DUIC. Because of their theoretical and actual association with dangerous driving scales, as well as with DUIC (Asbridge et al., 2005; Blows et al., 2005; Wells-Parker et al., 2002), the interaction between sensation seeking and impulsivity was also investigated. Results show that beyond age and driving exposure, sensation seeking is a psychological predictor of DUIC. Thus, individuals scoring high on sensation seeking show an elevated risk of driving under the influence of cannabis. These findings corroborate the literature on psychological predictors of driving under the influence of drugs (Beirness & Porath-Waller, 2009; Freeman et al., 2012; Lambert-Bélanger, Dubois, Weaver, Mullen, & Bédard, 2012) and confirm the importance of considering sensation seeking when intervening with DUIC drivers. Finally, unlike previous studies that have compared users and non-users of cannabis in samples grouping together young and middle-aged adults (Beasley et al., 2011; Richer & Bergeron, 2009; Smiley, 1999; Terry & Wright, 2005), neither age nor driving exposure was found to be a significant predictor of DUIC in the present study. This may be due to the fact that the present participants, all of whom were cannabis consumers, were between 18 and 25 years, a period when cannabis consumption is much higher and driving exposure is less than in the older age groups (Adlaf, Bégin, & Sawka, 2005; Laumon et al., 2005; Thompson, 2012; Young, 2011).

The third objective in the present work was to verify by means of logistic regressions whether frequency of DUIC is associated with an elevated risk of traffic violations and/or on-road accidents after controlling for identified confounding factors. Findings show that age, driving

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exposure, and risky driving are each positively and significantly associated with traffic tickets in the past three years. Self-report DUIC is also significantly associated with an increased risk of traffic tickets (e.g., for excessive speed or omitting a stop) and with self-report risky behaviors, but was not found to be a risk factor for motor vehicle accidents. As has been already suggested, the DDDI scores are in part composed of risky driving and negative emotional driving, which are not always related with traffic crashes. Indeed, risky drivers might also have good driving skills and reflexes; thus, avoid collisions.

Taken together, results indicate that self-reported DUIC is associated with a risky driving style, including a broad range of reckless on-road behaviors and support the problem driving behavior theory. However, these results do not inform on the specific effect of cannabis on driving skills nor suggest a causal link between DUIC and driving records.

4.1. Implications

The lifestyle and personality factors investigated in the current study appear to have an additive and interactive effect in encouraging risky driving among cannabis users, especially among those who frequently drive a car within hours after consuming cannabis. Levels of self-reported risky driving were statistically predicted by a combined factor that included the variables of DUIC frequency, sensation seeking, and driving exposure. Similarly, the self-reported risky driving was also positively correlated with direct observations of risky behaviors in a driving simulator and with the number of traffic tickets received during the last three years. This allows for propositions to be made with respect to adapting intervention strategies for cannabis users and DUIC drivers.

According to the individual difference model of information exposure (Donohew et al., 2000), high sensation seekers tend to be more receptive and more attentive to messages with high sensation value or inducing high stimulation. They tend to make decision on the basis of affective and physiological cues. This kind of "irrational" decision-making may lead to risk-taking such as DUIC. Intervention messages addressed to high sensation seekers should include an arousing and unconventional format. However, media campaigns promoting traffic safety tend generally to emphasize rational decision-making processes involved in driving. For impulsive and high sensation seekers this kind of behavioral skills intervention can become redundant and boring. Thus, it is important to bring a balance between arousal and education.

Moreover, with respect to DUIA, combinations of interventions based on an overall increase in penalties, the proliferation of awareness campaigns, and interventions directly targeted at the most at-risk groups have encouraged the notion that DUIA is a significant threat to road safety. Additionally, these efforts also raised awareness that alcohol consumption itself can be a major health problem. Overall, these campaigns have met with success; sizable reductions in the incidence of DUIA in the majority of industrialized nations and developing countries have followed the implementation of punitive and awareness-raising campaigns. It should be noted that while there have been broad and sweeping attempts at curbing risky driving habits and DUIA, DUIC remains a largely unaddressed problem.

Over time, strict road safety laws have come to severely punish DUIA drivers. These penalties have further been reinforced by ever-growing disapproval for DUIA by the public at large. And yet, despite an increase in the consumption of cannabis, there has been no comparable public outcry against the dangers of DUIC (Fergusson et al., 2008). This state of affairs reflects low public awareness of the pernicious effects that consuming cannabis can have on safe driving. Among the barriers to effecting changes in cannabis user behavior is the widely-held belief that the cannabis-detection tools currently available to law enforcement officials are poor (Davey, Davies, French, William, & Lang, 2005). Indeed, despite new methods currently used in the detection of cannabis, efforts at increasing public knowledge regarding DUIC are hindered by the social perception that there is no rapid and reliable techniques for detecting cannabis intoxication (Reisfield, Goldberger, Gold, & DuPont, 2012; Thompson, 2012).

Important public awareness campaigns should be aimed at and marketed towards the driving population aged 18 to 25, since this group is most likely to regularly use cannabis and is also likely to acknowledge having operated a motor vehicle shortly after consuming cannabis. Moreover, this population possesses less actual on-road driving experience, may be more prone to engaging in risk-taking driving behavior, and may be more naïve to the substance's psychoactive effects. This population also reports a greater likelihood of having driven after using cannabis in combinations with other illicit drugs or alcohol (Armentano, 2013; Swift, Jones, & Donnelly, 2010).

Anti-DUIC programs and strategies would have to target not only cannabis users but also their social environment (Lopez-Quintero & Neumark, 2010). That is, to maximize the chances of success, it would be necessary to provide intervention at both the level of the individual and the level of his/her immediate circle. Additionally, given the generally favorable societal opinion on cannabis, awareness campaigns should be targeting even younger children than those in alcohol campaigns. To really shift public opinion, socialization needs to begin earlier in child development.

4.2. Limitations and future studies

This study is not without limitations. Its strength relies in the multifaceted approach used to measure risk-taking driving that is self-reported questionnaires and direct observation of behaviors in a driving simulator. Most traffic safety studies investigating reckless driving used only retrospective self-reported measures. Self-report scales are sensitive to recall biases, purposeful or unintentional misreporting, and they share measure errors with other self-reported measures (Schwebel, Severson, Ball, & Rizzo, 2006). Thus, some data of the present study may have been subject to estimation errors (e.g., kilometers traveled) and or social desirability biases; however, at least in the latter case, it seems probable that such biased responding would serve to weaken the strength of the study's findings. It would be interesting to examine whether the influence of driver experience would remain similar if a different indicator such as kilometers driven during the last year was used. Another limit refers to the DUIC measure. The question asked to the participants was stated as follows: "How often did you drive within the hour following cannabis use in the previous 12 months." Clearly, this measure do not control for the concomitant use of other substances.

The driving simulator part of the study carries the same inherent limitation as do laboratory-based studies: weakness of ecological validity. In the present study, the intention underlying behaviors manifested in the simulator was not assessed. A future qualitative study would mitigate this limitation by documenting the subjective experience of participants following tasks on the driving simulator. Similarly, collision and traffic violation involvement was assessed by retrospective self-reported number of traffic crashes, and by retrospective self-reported number of traffic tickets in real-life driving. Measuring these variables by official records would have increased the validity of the measures. Nevertheless, in this study, associations between self-reported real-life driving and observed behaviors support the validity of these measures.

Finally, due to the sample size and recruitment method, the sample cannot be labeled as representative of the entire population of young drivers who are cannabis users. The sample included men only. Future research should include both men and women and investigate gender differences.

5. Conclusion

Self-reported DUIC is associated with a risky driving style including a broad range of reckless on-road behaviors. These results suggest that attempts to address DUIC face significant challenges, particularly using non-deterrence-based strategies. Since cannabis usage and DUIC appear

to be related to an overall reckless style of driving, it is proposed that public safety policies should be more holistic, simultaneously targeting multiple on-road dangerous behaviors for intervention.

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References

Adlaf, E. M., Bégin, O., & Sawka, E. (2005). *Canadian Addiction Survey (CAS): A national survey of Canadians' use of alcohol and other drugs.* Prevalence of use and related harms: Detailed report. Ottawa: Canadian Centre on Substance Abuse.

Armentano, P. (2013). Cannabis and psychomotor performance: A rational review of the evidence and implications for public policy. *Drug Testing and Analysis*, *5*(1), 52–56. http://dx.doi.org/10.1002/dta.1404.

Asbridge, M., Hayden, J. A., & Cartwright, J. L. (2012). Acute cannabis consumption and motor vehicle collision risk: Systematic review of observational studies and meta-analysis. *British Medical Journal*, *344*(e536), 1–9.

Asbridge, M., Poulin, C., & Donato, A. (2005). Motor vehicle collision risk ad driving under the influence of cannabis: Evidence from adolescents in Atlantic Canada. *Accident Analysis and Prevention*, *37*, 1025–1034.

Bates, M. N., & Blakely, T. A. (1999). Role of cannabis in motor vehicle crashes. *Epidemiologic Reviews*, *21*, 222–232.

Baumberger, B., Bergeron, J., Fluckiger, M., Paquette, M., & Delorme, A. (2006). Perception of relative distance in a driving simulator. *Japanese Psychological Research*, *47*(3), 230–237.

Bayle, F., Bourdel, M., Caci, H., Gorwood, P., Chignon, J., Ades, J., et al. (2000). Factor analysis of french translation of the Barratt impulsivity scale (BIS-10). *Canadian Journal of Psychiatry. Revue Canadienne de Psychiatrie*, *45*(2), 156.

Beasley, E., Beirness, D., & Porath-Waller, A. (2011). *A comparison of drug- and alcohol-involved motor vehicle driver fatalities.* : Canadian Centre on Substance Abuse.

Bédard, M., Dubois, S., & Weaver, B. (2007). The impact of cannabis on driving. *Canadian Journal of Public Health*, *98*(1), 6–11.

Beirness, D. J., & Beasley, E. (2009). *Alcohol and drug use among drivers: British Columbia Roadside Survey 2008.* Ottawa, ON: Canadian Centre on Substance Abuse.

Beirness, D. J., & Porath-Waller, A. J. (2009). *Clearing the smoke on cannabis: Cannabis use and driving.* Ottawa (Ont.): Canadian Centre on Substance Abuse.

Berghaus, G., Scheer, N., & Schmist, P. (1995). Effect of cannabis on psychomotor skills and driving performance — A meta-analysis of experimental studies. In C. N. Kloeden, & A. J. McLean (Eds.), *Proceedings of the 13th International Conference on Alcohol, Drugs and Traffic Safety, Vol. 1.* (pp. 403–409). Adelaide: NHMRC Road Accident Research Unit.

Blows, S., Ivers, R. Q., Ameratunga, S., Connor, J., Woodward, M., & Norton, R. (2005). Marijuana use and car crash injury. *Addiction*, *100*(5), 605–611.

Carton, S., Lacour, C., Jouvent, R., & Widlocher, D. (1990). Le concept de recherche de sensations: Traduction et validation de l'échelle de Zuckerman. *Psychiatrie & Psychobiologie*, *5*(1), 39–48.

Davey, J., Davies, A., French, N., Williams, C., & Lang, C. P. (2005). Drug driving from a user's perspective. *Drugs: Education, Prevention and Policy*, *12*(1), 61–70.

De Pelsmacker, P., & Janssens, W. (2007). The effect of norms, attitudes and habits on speeding behavior: Scale development and model building and estimation. *Accident Analysis and Prevention*, *39*(1), 6–15.

Donohew, L., Zimmerman, R., Cupp, P. S., Novak, S., Colon, S., & Abell, R. (2000). Sensation seeking impulsive decision-making and risky sex: Implication for risk-taking and design of intervention. *Personality and Individual Differences*, *28*, 1079–1091.

Downey, L. A., King, R., Papafotiou, K., Swann, P., Ogden, E., Boorman, M., et al. (2013). The effects of cannabis and alcohol on simulated driving: Influences of dose and experience. *Accident Analysis and Prevention*, *50*, 879–886.

Drummer, O. H., Gerostamoulos, J., Batziris, H., Chu, M., Caplehorn, J., Robertson, M. D., et al. (2004). The involvement of drugs in drivers of motor vehicles killed in Australian road traffic crashes. *Accident Analysis and Prevention*, *36*, 239–248.

Dula, C. S., & Ballard, M. E. (2003). Development and evaluation of a measure of dangerous, aggressive, negative emotional, and risky driving. *Journal of Applied Social Psychology*, *33*(2), 263–282.

Elander, J., West, R., & French, D. (1993). Behavioral correlates of individual differences in road-traffic crash risk: An examination method and findings. *Psychological Bulletin*, *113*(2), 279–294.

Fergusson, D. M., Horwood, L. J., & Boden, J. M. (2008). Is driving under the influence of cannabis becoming a greater risk to driver safety than drink driving? Findings from a longitudinal study. *Accident Analysis and Prevention*, *40*, 1345–1350.

Freeman, J., Scott-Parker, B., Wong, I., & Haworth, N. (2012). Vulnerable road user groups: A review of younger drivers, motorcyclists and older drivers. *Vulnerable Groups & Inclusion*, *3*.

Jessor, R., Donovan, J. E., & Costa, F. (1991). *Beyond adolescence: Problem behavior and young adult development.* : Cambridge University Press.

Johnson, M. B., Kelley-Baker, T., Voas, R. B., & Lacey, J. H. (2012). The prevalence of cannabis-involved driving in California. *Drug and Alcohol Dependence*, *123*(1), 105–109.

Jonah, B. A. (1990). Psychosocial characteristics of impaired drivers: An integrated review in relation to problem behavior theory. In R. J. Wilson, & R. E. Mann (Eds.), *Drinking and driving* (pp. 13–41). New York: The Guilford Press.

Kilmer, J. R., Hunt, S. B., Lee, C. M., & Neighbors, C. (2007). Marijuana use, risk perception, and consequences: Is perceived risk congruent with reality? *Addictive Behaviors*, *32*, 3026–3033.

Kurtzthaler, I., Hummer, M., Miller, C., Sperner-Unterweger, B., Günther, V., Wechdorn, H., et al. (1999). Effects of cannabis use on cognitive functions and driving ability. *Journal of Clinical Psychiatry*, *60*(6), 395–399.

Lambert-Bélanger, A., Dubois, S., Weaver, B., Mullen, N., & Bédard, M. (2012). Aggressive driving behaviour in young drivers (aged 16 through 25) involved in fatal crashes. *Journal of Safety Research*, *43*(5–6), 333–338.

Laumon, B., Gadegbeku, B., Martin, J. L., & Biecheler, M. B. (2005). Cannabis intoxication and fatal road crashes in France: Population based case–control study. *British Medical Journal*, *331*, 1371–1374.

Lenné, M. G., Dietze, P. M., Triggs, T. J., Walmsley, S., Murphy, B., & Redman, J. R. (2010). The effects of cannabis and alcohol on simulated arterial driving: Influences of driving experience and task demand. *Accident Analysis and Prevention*, *42*(3), 859–866. http://dx.doi.org/10.1016/j.aap.2009.04.021.

Lopez-Quintero, C., & Neumark, Y. (2010). Effects of risk perception of marijuana use on marijuana use and intentions to use among adolescents in Bogota, Colombia. *Drug and Alcohol Dependence*, *109*, 65–72.

Mann, R. E., Adlaf, E., Zhao, J., Stoduto, G., Ialomiteanu, A., Smart, R. G., et al. (2007). Cannabis use and self-reported collisions in a representative sample of adult drivers. *Journal of Safety Research*, *38*, 669–674.

Moskowitz, H. (1985). Marijuana and driving. *Accident Analysis and Prevention*, *17*(4), 323–345.

Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the Barratt impulsiveness scale. *Journal of Clinical Psychology*, *51*(6), 768–774.

Reimer, B., D'Ambrosio, L. A., Coughlin, J. F., Kafrissen, M. E., & Biederman, J. (2006). Using self-reported data to assess the validity of driving simulation data. *Behavior Research Methods*, *38*(2), 314–324.

Reisfield, G. M., Goldberger, B. A., Gold, M. S., & DuPont, R. L. (2012). The mirage of impairing drug concentration thresholds: A rationale for zero tolerance per se driving under the influence of drugs laws. *Journal of Analytical Toxicology*, *36*(5), 353–356.

Richer, I., & Bergeron, J. (2009). Driving under the influence of cannabis: Links with dangerous driving, psychological predictors, and accident involvement. *Accident Analysis and Prevention*, *41*(2), 299–307.

Richer, I., & Bergeron, J. (2012). Differentiating risky and aggressive driving: Further support of the internal validity of the Dula Dangerous Driving Index. *Accident Analysis and Prevention*, *45*, 620–627.

Schwebel, D. C., Severson, J., Ball, K. K., & Rizzo, M. (2006). Individual difference factors in risky driving: the roles of anger/hostility, conscientiousness and sensation seeking. *Accident Analysis and Prevention*, *38*, 801–810.

Smiley, A. (1999). Marijuana: on-road and driving-simulator studies. In H. Kalant, W. A. Corrigall, W. Hall, & R. Smart (Eds.), *The health effects of cannabis* (pp. 173–191). Toronto: Centre for Addiction and Mental Health.

Swift, W., Jones, C., & Donnelly, N. (2010). Cannabis use while driving: A descriptive study of Australian cannabis users. *Drugs: Education, Prevention and Policy*, *17*(5), 573–586.

Terry, P., & Wright, K. A. (2005). Self-reported driving behaviour and attitudes towards driving under the influence of cannabis among three different user groups in England. *Addictive Behaviors*, *30*, 619–626.

Thompson, P. (2012). Changing trends of drug driving detections in South Australia. *Paper presented at the Australasian Road Safety Research Policing Education Conference, 2012, Wellington, New Zealand.*

Walsh, G. W., & Mann, R. E. (1999). On the high road: Driving under the influence of cannabis in Ontario, Canada. *Journal of Public Health*, *90*, 260–263.

Wells-Parker, E., Ceminsky, J., Hallberg, V., Snow, R. W., Dunaway, G., Guiling, S., et al. (2002). An exploratory study of the relationship between road rage and crash experience in a representative sample of US drivers. *Accident Analysis & Prevention*, *34*(3), 271–278.

Willemsen, J., Dula, C. S., Declercq, F., & Verhaeghe, P. (2008). The Dula Dangerous Driving Index: An investigation of reliability and validity across cultures. *Accident Analysis and Prevention*, *40*(2), 798–806.

World Drug Report (2011). *World Drug Report. Volume 1: Analysis. Cannabis market.* : United Nations Office on Drugs and Crime.

Young, M. M. (2011). Cross-Canada report on student alcohol and drug use. *Technical report*. Ottawa, Ontario: Canadian Center on Substance Abuse.

Zuckerman, M. (1994). *Behavioral expressions and biosocial bases of sensation seeking.* New York: Cambridge University Press.

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